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MILITARY SPECIFICATION

ALUMINUM-ALLOY CASTINGS, HIGH STRENGTH

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for six alloy compositions, four inspection classes, four radiographic quality grades and six classes of mechanical properties of high strength aluminum-alloy castings.

1.2 Classification. Aluminum-alloy castings shall be furnished in the following compositions, grades and classes, as specified (see 6.2.1):

1.2.1 Composition. The chemical composition of the castings shall conform to Table I, which consists of alloys A201.0, 354.0, C355.0, A356.0, A357.0 and 359.0. Unified Numbering System (UNS) for these alloys are: A12010, A03540, A33550, A13560, A13570 and A03590 respectively.

1.2.2 Inspection class. Castings shall be classified with respect to criticality of application as defined by MIL-STD-2175, and each casting drawing shall specify the class required for the application (see 6.2.1).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Systems Engineering and Standardization Department (Code 93), Naval Air Engineering Center, Lakehurst, NJ 08733, using the self-addressed Standardization Document Improvement proposal (DD Form 1426) appearing at the end of this document or by letter.

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1.2.3 Radiographic grade. The radiographic inspection quality grades shall be as follows (see Table II):

<u>Grade</u>	<u>Description</u>
A	A highly stressed casting or area of a casting for critical application.
B	A premium grade of casting for critical applications or specified area of a casting with low margins of safety.
C	A high quality grade of casting for general applications or area of a casting with average margin of safety.
D	A casting or area of a casting subjected only to low stresses.

1.2.4 Mechanical property class. The mechanical property class of each casting or area of a casting shall be as specified in Table III and IV, as applicable, unless mechanical property requirements are specified on the engineering drawing. Classes are identified as Class 1, 2 or 3 (for designated areas) or 10, 11 or 12 (for any area), as applicable, for the alloy specified.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified, the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-H-6088	-	Heat Treatment of Aluminum Alloys
MIL-I-6866	-	Inspection, Penetrant Method of
MIL-I-25135	-	Inspection Materials, Penetrants

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STANDARDS

FEDERAL

FED-STD-151 - Metals, Test Methods

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
 MIL-STD-129 - Marking for Shipment and Storage
 MIL-STD-410 - Nondestructive Testing Personnel Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic and Ultrasonic)
 MIL-STD-453 - Inspection, Radiographic
 MIL-STD-649 - Aluminum and Magnesium Products, Preparation for Shipment and Storage
 MIL-STD-1537 - Electrical Conductivity Test for Measurement of Heat Treatment of Aluminum Alloys, Eddy Current Method
 MIL-STD-2175 - Castings, Classification and Inspection of

(Copies of specifications and standards required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, unless otherwise specified.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM B 557 - Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products
 ASTM E 29 - Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values
 ASTM E 155 - Reference Radiographs for Inspection of Aluminum and Magnesium Castings

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

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SAE

AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 3025 - Polyalkylene Glycol Heat Treat Quenchant

(Application for copies should be addressed to SAE, 400 Commonwealth Drive, Warrendale, PA 15096.)

NATIONAL AEROSPACE STANDARDS (NAS)

NAS 823 - Cast Surface Comparison Standard

(Applications for copies of this document should be addressed to National Standards Association, Inc., 5161 River Road, Bethesda, MD 20816.)

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3. REQUIREMENTS

3.1 First article. Sample castings shall be subjected to first article inspection, unless such inspection has been waived (see 3.2.1.1, 4.3, 6.2.1, and 6.3).

3.2 Foundry practice.

3.2.1 Process control approval.

3.2.1.1 Foundry control approval. Production of a given casting shall not begin until the foundry control is approved. If temporary gating was used, castings shall be made with the gating installed. The following shall be recorded where applicable: molten metal holding temperature, pouring temperature, degassing procedure, grain refining and modification procedures, chill and insulation sizes and locations, gating techniques and procedures, filtering techniques, and risering techniques, procedures and locations. Approval of foundry control shall be based on the results of first article inspection, unless such inspection has been waived (see 3.1). Where there is no waiver of first article inspection, the foundry shall be required to use the same casting practice and heat-treating procedure for the production castings as for the approved first article castings. If necessary to make any change in production procedures (see 3.2.2), the foundry shall notify the

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purchaser of the proposed change prior to the first shipment of castings. The foundry shall submit a sample production casting produced by the changed procedure for inspection for process approval (see 6.2.1).

3.2.1.2 Surface roughness control approval. Where surface roughness is specified on a drawing of a given casting or elsewhere in the acquisition documents (see 6.2.1), production of this casting shall not begin until control of surface roughness is approved. Such control may be established by any method of mold preparation or subsequent surface finishing appropriate for the purpose, unless the method is expressly forbidden in the acquisition documents. The purchaser shall be notified of the intended method for surface roughness control. Approval of surface roughness control shall be based on the results of first article inspection, unless such inspection has been waived (see 3.1). Where there is no waiver of first article inspection, the foundry shall use the same surface roughness control method for the production castings as for the approved first article castings. Where first article inspection has been waived, the foundry shall be required to use a surface roughness control method acceptable to the purchaser. If it is necessary to make any change in surface roughness control, the purchaser shall be notified of the proposed change prior to the first shipment of production castings. The foundry shall submit a sample production casting using the changed procedure for inspection for process approval (see 6.2.1).

3.2.1.3 Order of establishment of controls. When surface roughness is specified (see 6.2.1), approval of foundry control shall be obtained prior to approval of surface roughness control. When first article inspection for foundry control has not been waived, first article castings shall be submitted for approval without finished surfaces, if surface finishing is to be performed subsequent to casting.

3.2.2 Changes in foundry practice. A sample production casting, new first article, shall be submitted for approval whenever one or more of the changes listed below occur(s). The purchaser may waive this requirement after review of the change(s).

- a. When a new pattern or permanent mold is made.
- b. For each new pattern or cavity in multiple tooling.
- c. When a duplicate pattern or mold is made.
- d. When any change is made in gates, runner system, risers or chills.
- e. When any change in the "as cast" shape is made.
- f. When strength requirements are raised.

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- g. When an old pattern is transferred to a new vendor, or a new facility.
- h. When another alloy is used.
- i. When melting or processing techniques are changed.
- j. When an existing pattern is re-rigged or remounted.
- k. When mold systems are changed.

3.3 Composition.

3.3.1 Chemical composition of castings. The chemical composition of castings shall be as specified in Table I.

3.3.2 Chemical analysis. Analysis shall routinely be made only for the elements specifically mentioned in Table I. If however, the presence of other elements is suspected or indicated in the course of routine analysis, further analysis shall be made to determine conformance to the limits specified for other elements.

3.4 Radiographic and surface requirements.

3.4.1 Process control castings (first article foundry control).

3.4.1.1 Radiographic soundness, mechanical property and surface roughness control. Prior to production of a given casting, radiographic, mechanical property and, when specified (see 6.2.1), surface roughness controls shall be established. Sample castings (see 4.3.1) shall be examined by radiographic methods aided by sectioning and etching to determine the presence of internal defects. In addition, the full-size casting or tension test specimens machined from castings or cast-on coupons (where permitted) shall be tested for conformance to the required mechanical properties. The full-size casting, either as-cast or surface-finished, shall be tested for roughness, when roughness requirements are specified on the casting drawing or other acquisition documents. In order for foundry control to be acceptable, each location of a casting must exhibit soundness, surface roughness, and tensile properties conforming to those specified for that location on the drawing or other acquisition document. When acceptable foundry practices have been established, the production method shall not be changed (see 3.2.2) without demonstrating to the satisfaction of the purchaser that the change does not adversely affect the quality of the casting.

3.4.1.1.1 Radiographic inspection. The casting shall be radiographically inspected for acceptability of the casting process in relation to the soundness requirements of 3.4.1.1.2. Inspection procedures shall conform to 4.5.2.

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3.4.1.1.2 Soundness. Unless otherwise specified in the contract or order, the severity of the discontinuities shall not be greater than that shown in Table II for the applicable quality standard specified. Discontinuities revealed by the radiograph of the casting shall be matched to the comparable ASTM E 155 reference radiograph for a particular discontinuity. The matching reference radiograph indicates the relative severity of the discontinuity, and that number shall be equal to or less than the number in Table II. Where "none" appears in Table II, none of the applicable discontinuities shall be permissible in the castings.

3.4.1.1.3 Mechanical properties. Once conformance to Table II is established, conforming castings shall exhibit mechanical properties meeting the applicable requirements of Tables III and IV or as specified in the casting drawing, when tested in accordance with 4.5.4. Specimens for the tension test shall represent as a minimum those locations subjected to high stresses, or identified as critical, and other locations (see 4.4.2.4.2) containing the most severe discontinuities within specified standards. From the latter locations specimens shall be removed when requested by the purchaser (see 6.2.1). Castings which exhibit soundness and mechanical properties, both of which are borderline, shall be cause for disapproval of foundry control.

3.4.1.1.3.1 Mechanical properties of large castings. Where the casting is large (over 100 pounds poured weight), specimen blanks shall be removed in accordance with 4.4.2.4.4. Specimens shall be tested for compliance with Tables III and IV, or as specified on casting drawing, as applicable. All specimens made from excised blanks or gates, or from integrally cast test bars shall exhibit properties representative of the properties of locations within the casting adjacent to those locations from which blanks for these specimens were removed.

3.4.1.1.4 Surface quality. Foundry control castings shall not contain cracks, cold shuts, or foreign material in excess of that allowed by the applicable radiographic quality grade specified, when inspected in accordance with 4.5.3. When specified (see 6.2.1), surface roughness in any location shall not exceed the maximum specified for that location.

3.4.1.1.5 Electrical conductivity. When applicable, the foundry control casting shall meet the requirement of 3.4.4.

3.4.2 Production castings.

3.4.2.1 Radiographic requirements. After the foundry practices of 3.2 have been established, castings shall be radiographically inspected as specified in 4.5.2. Acceptance shall be by comparison with the applicable standard set of radiographs contained in ASTM E 155 or with other standards approved by the purchaser (see 6.6). Radiographic indications shall be identified in terms of the discontinuities listed in Table II. Acceptance shall be made in accordance with the grade specified on the engineering drawing (see 1.2.3). When no grade is specified, Grade C shall apply.

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3.4.2.2 Radiographic acceptability. Unless otherwise specified (see 6.2.1), radiographic acceptability shall comply with Table II. Radiographic acceptability is indicated by the applicable reference ASTM E 155 radiograph which is acceptable for the specified grade, or such acceptability is indicated by the applicable radiograph in an alternate standard set (see 6.6). To be acceptable as to the specified grade, a casting must be acceptable for all discontinuities listed in Table II relative to that grade. Nonconformance with the applicable standard for any single defect shall make a casting unacceptable. Unacceptable shrinkage, porosity or sponge in alloy A201.0 may assume a radiographic appearance similar to mottling, and when this condition is suspected, metallographic examination is required.

3.4.3 Mechanical properties. The mechanical properties of test specimens, taken as specified in 4.4.2.4, shall conform to the applicable requirements of Tables III and IV or as specified on the drawing. The strength requirement of the casting tested in full-size shall be as specified in the drawing for the part concerned or in other purchase information.

3.4.4 Electrical conductivity. The electrical conductivity of Alloy A201.0 in the -T7 temper shall be 31.0 percent or greater, International Annealed Copper Standard (IACS).

3.4.5 Surface roughness. When specified, maximum surface roughness in any area of a casting shall be that specified in drawings of the casting or in other acquisition documents, and shall be expressed in terms of comparator numbers on as-cast surfaces and in terms of height ratings on machined or ground surfaces including gate and riser areas. Surfaces other than as-cast shall not have a roughness exceeding that of an as cast surface. Comparison standards used for measuring surface roughness shall be as specified in the acquisition documents (see 6.2.1).

3.5 Heat treatment. Unless otherwise specified on a casting drawing or elsewhere in the acquisition documents, castings shall be heat-treated in accordance with MIL-H-6088 except as modified herein. Castings of alloys A201.0, 354.0, A357.0 and 359.0 shall be solution heat-treated within the range of temperatures specified in Table V of this specification. An aqueous solution of polyalkylene glycol meeting the requirements of AMS 3025 may be used as a quenchant to minimize distortion, provided that the castings meet the mechanical property requirements of this specification or applicable drawing. Heat treatment shall be performed on a whole casting and never on a portion only. Castings shall be artificially aged by heating uniformly over the time and at the temperature necessary to obtain the required mechanical properties. The recommended time and temperature cycle for precipitation heat treatment of alloy A201.0, 354.0, A357.0, and 359.0 are shown in Table VI.

3.6 Marking. Unless otherwise specified on the casting drawing, castings shall be identified with a part number and a serial number or lot number, and radiographic control number (see 6.2.1). Markings shall be so located as to be preserved throughout the finishing process.

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3.6.1 Method of identification. Identification markings shall be raised numerals or letters when specified on the casting drawing and in the location noted.

3.6.2 Alternate method of identification. Identification shall be by marking with indelible ink, or tagging when no method is specified on the drawing, or when it is impractical to provide raised letters or numerals.

3.7 Casting dimensions. The dimensions of the castings shall be within the dimensions and tolerances specified on the applicable drawings.

3.8 Workmanship. Castings shall be uniform in quality and condition, sound, clean, and substantially free from foreign materials.

3.8.1 Weld repair of castings. Castings may be weld repaired only upon written permission of the purchaser. The granting of such permission requires that the facility performing repairs demonstrate that repaired castings will meet all applicable quality requirements of this specification. Further, weld procedures for repair and welder qualifications shall be acceptable to the purchaser. In any repaired casting, repaired areas shall conform to all quality requirements specified for that area on the drawing or in other acquisition documents. Repaired castings shall be subjected to the same inspections and meet the same acceptance criteria as a casting which is sound in the same areas. Such areas shall be identified to facilitate inspection. Repairs shall be made prior to final solution heat treatment and inspections specified herein, and prior to any surface finishing treatment (see 6.5 for precautions for welding A357.0 alloy).

3.8.2 Straightening of castings. Castings shall not be mechanically straightened after artificial aging treatment without written permission from the purchaser.

3.8.3 Prevention of leaks. Castings shall not be impregnated, chemically treated, or coated to prevent leaking, unless specified by the purchaser. Impregnated castings shall be marked IMP.

3.8.4 Radiographic quality. Radiographic standards shall be as specified on the drawing or purchase order in accordance with 3.4.2.1.

3.8.5 Surface quality. Castings shall not contain surface cracks, cold shuts, or foreign material adhering to or embedded in the surface, when inspected in accordance with 4.5.3. Surface projections, such as those remaining after removal of gates and risers, shall not rise higher than limits specified in drawings or in other acquisition documents (see 6.2.1).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use

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his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Certification of quality compliance. Certificates of quality compliance (see 6.2.2) shall be prepared for each lot of material offered for acceptance. The certificate shall include results of specified chemical and mechanical tests. Qualitative results of nondestructive tests and other inspections or tests shall be recorded on the certificate. The certificate shall also state that each lot has been sampled, tested, and inspected in accordance with the specification and meets all requirements. The certificate shall be signed by a responsible representative of the contractor, and shipped with the lot.

4.2 Classification of inspection. The inspection requirements specified herein are classified as follows:

- a. First article inspection (see 4.3).
- b. Quality conformance inspection (see 4.4).

4.3. First article inspection. First article inspection for foundry control shall consist of all the requirements of this specification.

4.3.1 First article sample. A first article sample shall consist of two castings, solution heat treated, straightened and aged to drawing requirements and submitted for inspection and approval as directed by the purchaser. One casting shall be identified as the "dimensional sample" and shall be for dimensional approval. The other casting shall be identified as, "foundry control sample" and shall be subjected to composition, X-ray, mechanical property, and other tests and inspections as necessary for approval (see 6.2.1 and 6.3).

4.4 Quality conformance inspection. This inspection shall consist of all tests and inspections specified in 4.5.

4.4.1 Inspection lots. Inspection lots shall be classified as melting lots or casting lots as defined herein.

4.4.1.1 Melting lot (heat). A melting lot, hereinafter named "heat", shall be one batch of alloy melted then poured within a substantially brief and continuous time period (8 hours). The unit of inspection shall be the heat itself.

4.4.1.2 Casting lot. Unless otherwise specified (see 6.2.1), a casting lot shall consist of not more than 1000 pounds of castings of the same part which are poured from a single heat and

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which are heat-treated in one furnace load and manufactured by the same production technique. The unit of inspection shall be one casting.

4.4.2 Sampling instructions. Unless otherwise specified herein or on the drawing or other purchase information and where applicable, sampling plans and procedures in the determination of the acceptability of products shall be in accordance with the provisions set forth in MIL-STD-105 or MIL-STD-2175 where specified (see 6.2.1).

4.4.2.1 Sampling for visual and dimensional examination. All castings shall be subjected to the visual and dimensional inspection specified in 4.5.6.

4.4.2.2 Sampling for chemical composition. Samples to determine conformance to 3.3.1 shall be taken from the heat. Samples from castings need not be taken unless compliance with 3.3.1 is questionable. All samples shall be subjected to the test of 4.5.1.

4.4.2.2.1 Samples from heats. A minimum of two samples shall be taken from each heat, one at the beginning of the pour into casting molds, the second at the termination of the pour. Additional samples may be taken during the course of the pour, if such are needed to determine that compliance with 3.3.1 is being maintained.

4.4.2.2.2 Samples from castings. When compliance with 3.3.1 has not been established for a particular melting lot of castings, a random sample from that casting lot shall be selected in accordance with MIL-STD-105, Inspection Level S-1, Acceptance Number Zero, Rejection Number 1, for the test of 4.5.1.

4.4.2.3 Sampling for penetrant and radiographic inspection.

4.4.2.3.1 Penetrant inspection. All castings in each lot shall be penetrant inspected in accordance with 4.5.3.

4.4.2.3.2 Radiographic inspection. Sample castings shall be inspected in accordance with 4.5.2. The number of castings to be radiographed shall be determined as follows. Following process control approval, from the first 10 production lots of a particular cast part, the number of castings selected from each lot for radiographic inspection shall, as identified by MIL-STD-2175 inspection class, be:

Classes 1 and 2 castings - Each casting in the lot shall be completely examined.

Class 3 castings - Sample size shall be selected in accordance with the table for Class 2 castings of MIL-STD-2175, and be completely examined.

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Class 4 castings - Sample size shall be selected in accordance with the table for Class 3 castings of MIL-STD-2175, and be completely examined, unless radiographic examination is waived in the acquisition documents (see 6.2.1).

Sampling shall remain at these levels until 10 casting lots of the part, produced consecutively, show compliance with soundness requirements. Once this condition is satisfied, inspection levels may be reduced to those levels specified in MIL-STD-2175, as applicable to class number.

4.4.2.4 Sampling for mechanical properties.

4.4.2.4.1 Lot sampling for castings. In the event that a casting radiographed according to 4.5.2 shows borderline soundness according to 3.4.2.2, that casting shall be among those subjected to the test specified in 4.5.4 together with other castings selected at random from the same lot. From such a casting, specimen blanks for test shall be removed in accordance with the directions of the purchaser. For the first 10 casting lots of a part produced following foundry control approval, the number of castings in the samples shall conform to the applicable sample size code letters listed under Inspection Level S-3 of MIL-STD-105, with an Acceptance Number Zero, and a Rejection Number 1. Sampling shall conform to the foregoing sampling plan until 10 casting lots of the part, produced consecutively, have been sampled and tension-tested, and have demonstrated properties complying with those specified herein. Once this condition is satisfied, samples may be sized in accordance with Inspection Level S-2 of MIL-STD-105, with an Acceptance Number Zero, and a Rejection Number 1.

4.4.2.4.2 Locations of specimens for tension tests. Following heat treatment, castings shall have test specimen blanks removed from locations shown on drawings, or as specified elsewhere in the acquisition documents (see 6.2.1). If no location is specified, three specimens shall be excised from a thick, medium and thin section of each casting selected at random and as approved by the purchaser. With the approval of the purchaser, test bars cast integrally with the casting may be tested in lieu of testing the casting itself, provided that the casting is too small for either excising test coupons or testing of the casting as a whole, and that the thickness of the test bars is equal to or greater than the thickness of the portions of the castings to which the bars are attached. Test bars shall not be removed from the casting until all heat treatments have been completed, unless the bars interfere with inspection processes or straightening whereupon they may be removed after solution heat treatment, but must accompany the associated casting during precipitation heat treatment.

4.4.2.4.3 Lot sampling for large castings. Where the size of a casting precludes obtaining a sample (over 100 pounds poured weight) from a single heat, integrally cast test bars from each casting in the lot shall be tested with an Acceptance Number Zero and a Rejection Number 1. Lot sizes greater than eight shall be sampled in accordance with Inspection Level S-3 of MIL-STD-105, with an Acceptance Number Zero and a Rejection Number 1. The Inspection Level shall remain S-3 until ten casting lots of a part, produced consecutively, have been sampled and tension-tested, and have demonstrated properties complying with those specified herein.

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Once this condition is satisfied, samples may be sized in accordance with Inspection Level S-2 of MIL-STD-105, with an Acceptance Number Zero, and a Rejection Number 1.

4.4.2.4.4 Locations of specimens for tension tests, large castings. The locations in the casting from which coupons for the tension test are to be taken shall be identified on the casting drawing. Test specimen blanks shall be excised after final heat treatment from the casting where feasible. Excision may be performed by deep trepanning or sawing, as applicable. If specimen blanks cannot be excised from the casting, they may be removed from gates adjacent to the locations of concern of the casting. When, at a given location of concern, specimen blanks cannot be excised from the casting, and there are no gates adjacent to that location, provision shall be made for integrally cast test bars to be attached to that location. Such bars shall not be removed until all heat treatments have been completed, unless the bars interfere with inspection processes or straightening whereupon they may be removed after solution treatment but must accompany the associated casting during precipitation heat treatment. From those castings which have specimen blanks cut from gates or have integrally cast test bars, one casting per each 25 casting lots shall be sectioned for test specimens in the locations where the test bars are attached. Specimens made from these specimen blanks shall be tension-tested together with the specimens made from test bars to ensure that approved foundry control is being maintained.

4.4.2.4.4.1 Sampling, large castings, separately cast test specimens. Alternatively, with the agreement of the purchaser, casting lot sizes of one to 8 castings may be sampled on the basis of heat treat batch. At least one casting shall be selected at random from each group of castings heat treated together in batch type furnaces. In addition, two or more separately cast tension test specimens shall be cast from each heat with the castings and heat treated with the castings of the same heat. All specimens shall be tension tested. Separately cast specimens shall meet Class 2 requirements.

4.4.2.5 Samples of A201.0-T7 for electrical conductivity test. Electrical conductivity tests (see 4.5.5) shall be performed on tension test specimens, blanks or parts of A201.0-T7, in order to determine compliance with the requirements of 3.4.4.

4.4.2.6 Sampling for surface roughness. When surface roughness has been specified for a casting or portion thereof (see 6.2.1), following process control approval, a random sample of castings shall be selected from each casting lot and inspected in accordance with 4.5.7. Samples from the first ten lots produced shall be sized in accordance with Inspection Level S-2 of MIL-STD-105, Acceptance Number Zero, Rejection Number 1. Such sizing shall be maintained until ten lots, produced consecutively, have demonstrated acceptability. Following such demonstration, samples shall be sized in accordance with Inspection Level S-1 of MIL-STD-105, Acceptance Number Zero, Rejection Number 1.

4.4.3 Noncompliance and retest. Failure of any sample or samples to conform to any one of the requirements of this specification shall make the lot represented by that sample or samples

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subject to rejection, except as otherwise provided in 4.4.3.1 or in a sampling plan approved by the acquiring activity.

4.4.3.1 Retest for mechanical properties. In the event of failure of one or more representative specimens to exhibit acceptable mechanical properties, retest of additional specimens from the lot will be permitted. Two additional specimens shall be tested for each original nonconforming specimen. The additional specimens shall be removed from the location from which the original specimens were taken or a location immediately adjacent to it provided that, the adjacent material is fully representative of the casting. If one of the retest samples fail, the lot shall be rejected as noncompliant and the requirements of 4.4.3.2 shall take effect.

4.4.3.2 Noncompliance. If after retest or resampling, a sample fails to pass any of the quality conformance inspections specified herein, the contractor shall notify the purchaser of such failure and take corrective action on the materials or processes, or both, as warranted, and on all units of product which can be corrected and which are manufactured under essentially the same materials and processes, and which are considered subject to the same failure. Acceptance and shipment of the product shall be discontinued until corrective action acceptable to the purchaser has been taken. After the corrective action has been taken, quality conformance inspections shall be repeated on additional sample units (all tests and inspections, or only that test or tests which the original sample failed, at the option of the purchaser). Shipment shall be withheld until all required inspections have shown that the corrective action was successful. In the event of failure after reinspection, information concerning the failure shall be furnished to the cognizant inspection activity and the acquisition activity (see 6.2.1).

4.4.4 Inspection of marking and packaging. Unless waived by the purchaser, castings shall be inspected before packaging for marking in compliance with 3.6 (see 6.2.1). From a shipping lot of identical castings, at least one pack shall be inspected for compliance with Section 5, unless otherwise specified.

4.5 Methods of inspection.

4.5.1 Chemical analysis. Analysis shall be by spectrographic or wet chemical methods in accordance with Methods 111.1 or 112.1 of FED-STD-151. In case of dispute, the chemical analysis by the wet chemical method shall be the basis for acceptance.

4.5.2 Radiographic inspection. This examination shall be conducted in accordance with MIL-STD-453. The limits of X-ray indications shall, unless otherwise noted, be as specified in 3.4.2.2. Additional radiographic inspection may be specified by the purchaser. Inspection personnel shall be certified to Level II as defined by MIL-STD-410 or as otherwise specified (see 6.2.1).

4.5.3 Penetrant inspection. Castings shall be penetrant inspected in accordance with MIL-I-6866, using Group V post-emulsified or Group IV water-washable penetrant or water-

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washable penetrant of equivalent sensitivity conforming to MIL-I-25135, to determine conformance to 3.8.5. Inspection personnel shall be certified to Level II as defined by MIL-STD-410, unless otherwise specified (see 6.2.1). If treatment is to be applied subsequent to casting, penetrant inspection shall be performed prior to such treatment.

4.5.4 Mechanical properties. Test methods for evaluating these properties shall conform to the specifications of ASTM B 557, as applicable. Test specimens shall be the standard round specimen of 0.500 inch diameter and 2.000 inches gauge length in the reduced section, where the dimensions of the location of the sample test castings so permit. When location dimensions do not permit the preparation of a full-size test specimen, small-size round or flat specimens may be tested as specified by the purchaser (see 6.2.1), or the full-size casting may be tested, or test specimens made from integrally cast bars may be tested when approved by the purchaser. When testing of a complete casting is required, the strength requirement and the direction or method of loading of the full-size casting shall be specified on the drawing for the part concerned (see 6.2.1).

4.5.5 Electrical conductivity. Samples taken in accordance with 4.4.2.5 shall be tested for electrical conductivity in accordance with MIL-STD-1537.

4.5.6 Visual and dimensional examination. Prior to surface finishing operations, if these are to be applied, castings shall be examined for surface imperfections, identification of product, dimensions, and workmanship requirements of 3.6, 3.7, and 3.8, respectively. When needed, a magnifying glass (up to 12X) may be used to aid visual inspection.

4.5.7 Inspection for surface roughness. Each sample casting submitted for inspection of surface roughness shall be inspected in areas designated on the casting drawing or on other acquisition documents. Inspection of the surfaces in the as-cast condition or surface finished condition, shall be by comparison with either the applicable standard reference block depicted in NAS 823 or with sections of the casting which have been mutually agreed upon by the purchaser and supplier as the surface roughness standard (see 6.2.1).

5. PACKAGING

5.1 Preservation. Castings shall be prepared for shipment in accordance with MIL-STD-649. The level of preservation shall be level A or C as specified (see 6.2.1).

5.2 Packing. Castings shall be packed in accordance with MIL-STD-649. The level of packing shall be level A, B, or C as specified (see 6.2.1).

5.3 Marking. Each container shall be marked in accordance with MIL-STD-129.

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6. NOTES

6.1 Intended use. The high strength aluminum alloy castings covered by this specification are intended for airframe, missile, and other applications where high strength, ductility, soundness, and uniform composition within each casting are required.

6.2 Ordering data.

6.2.1 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Alloy number, temper designation, grade and class of casting (see 1.2).
- c. Quantity desired.
- d. Applicable drawings.
- e. If first article inspection is waived (see 3.1, 4.3 and 6.3).
- f. Test facility for first article inspection and quality conformance inspection. Specify, if other than foundry is required to perform all the tests for such inspections for the purchaser.
- g. Surface quality and roughness requirements if not on the drawing (see 3.2.1.2, 3.4.1.1 and 3.8.5); whether any surface finishing methods are forbidden.
- h. Locations on castings for tests if not shown on drawing. Special instructions regarding small castings (see 4.5.4).
- i. Marking requirements (see 3.6).
- j. Applicable radiographic standards (see 3.4.1.1).
- k. Size of casting lot for inspection if other than 1000 pounds (see 4.4.1.2).
- l. Sampling instruction if other than as specified in 4.4.2.
- m. If inspection for casting marking is waived (see 4.4.4).
- n. Required qualifications of NDT personnel if other than Level II of MIL-STD-410 (see 4.5.2 and 4.5.3).

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- o. If radiographic examination for inspection of Class 4 castings is waived (see 4.4.2.3.2).
- p. Applicable surface roughness standard if other than NAS 823 (see 4.5.7).
- q. Selection of level of preservation and packing (see section 5).

6.2.2 Data requirements. When this specification is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of DAR 7-104.9 (n) (2) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this specification is cited in the following paragraph.

<u>Paragraph no.</u>	<u>Data requirements</u>	<u>Applicable DID no.</u>
4.1.1	Certification data report	UDI-A-23264

(Copies of data item descriptions required by contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.3 First article. When first article inspection has not been waived, the first article sample should be two castings submitted for inspection (see 4.3.1). Production castings should not be poured or submitted for inspection prior to first article approval. Acquisition documents should include specific instructions regarding arrangements for examinations, tests and approval of the first article. For first article inspection, the acquisition documents should include the following:

- a. Site of first article inspection (supplier's or contractor's facility, Government or commercial laboratory).
- b. Scheduling of first article inspection. When the casting supplier is to perform the testing, he should notify the purchaser in sufficient time to allow purchaser representation during testing.
- c. That the approval of first article samples or the waiving of first article inspection does not relieve the contractor of his responsibility to ensure that all requirements of the specification and contract are fulfilled.

6.4 Definitions. Some of the terms defined in this paragraph are so defined as to be especially pertinent to this specification. Their exact applicability to other specifications, standards and Federal publications is not certain.

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a. Acquiring activity. An organizational element of the Federal Government which buys, rents, leases, or otherwise obtains equipment, supplies, or services to meet the needs of the Federal Government.

b. Acquisition activity. Term synonymous with "acquiring activity."

c. Acquisition documents. Any diagrams, drawings, specifications, standards, handbooks, requests for bids, invitations for proposals, contracts, purchase orders, or other written instructions and illustrations used for acquisition. In this specification the term is restricted to documents dealing with the acquisition of high-strength aluminum-alloy castings. Such acquisition documents may include purchase orders or other documents generated by a private party who needs to acquire castings to fulfill a contract with the Federal Government.

d. Contract. An agreement between the Federal Government and a private party expressing terms and conditions affecting price, performance, and delivery of equipment, supplies, or services by the private party to the Federal Government or its designee. Contracts are legally binding and enforceable on both parties provided that the contracts meet certain criteria under law. Terms of a contract are not binding on anyone not a party to the contract.

e. Contractor. A private party, not a member of the Federal Government, who enters into a contract with the Federal Government. The term embraces a legal requirement, not a function, such as, manufacturer or test facility.

f. Foundry. A commercial establishment or building where metal castings are produced. A foundry may or may not be under an agreement with the Federal Government to supply castings for a particular acquisition. The foundry may be under contract to another private party to supply casting for incorporation into equipment which the latter party would supply to the Federal Government under another contract. In such a case, the Federal Government would hold the equipment supplier responsible for the performance of the foundry.

g. Purchaser. Either a contractor (see "e" above) or Government activity (see "a" above) which purchases castings directly from a casting supplier. The acquiring activity is always the ultimate purchaser of the castings whether the acquisition is direct or indirect.

h. First article inspection. Inspection at the time of the first production of a new casting by a foundry. Also, inspection following a change in configuration or in foundry practice which could affect casting test results (see 3.2.2).

6.5 Welding precautions for A357.0 alloy. Welding operations to repair castings of A357.0 alloy should include precautions against beryllium toxication of welders and other exposed personnel. Reference should be made to applicable OSHA regulations and literature concerning industrial toxicology for guidance in establishing safety controls.

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6.6 Reference radiographs. For radiographic inspection of certain castings of complex configuration it may be advisable that standard reference radiographs be developed using a casting itself. Adoption of such standards would entail approval by the acquiring activity and the contractor, if the latter is the direct purchaser of the castings.

6.7 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:

Army - MR

Navy - AS

Air Force - 20

Preparing activity:

Navy - AS

(Project MECA-0223)

Review activities:

Army - AR, AV, EA, ME, MI

Air Force - 70, 71, 80, 82, 84, 99

User activities:

Navy - SH

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TABLE I. Chemical composition. 1/

Elements	Alloy					
	A201.0	354.0	C355.0	A356.0	A357.0	359.0
Copper	4.0 of 5.0	1.6 to 2.0	1.0 to 1.5	0.20	0.20	0.20
Silicon	0.05	8.6 to 9.4	4.5 to 5.5	6.5 to 7.5	6.5 to 7.5	8.5 to 9.5
Iron	0.10	0.20	0.20	0.20	0.20	0.20
Manganese	0.20 to 0.40	0.10	0.10	0.10	0.10	0.10
Zinc	--	0.10	0.10	0.10	0.10	0.10
Magnesium	0.15 to 0.35	0.40 to 0.6	0.40 to 0.6	0.25 to 0.45	0.40 to 0.7	0.50 to 0.7
Titanium	0.15 to 0.35	.020	0.20	0.20	0.04 to 0.20	0.20
Beryllium	--	--	--	--	0.04 to 0.07	--
Silver	0.40 to 1.0	--	--	--	--	--
Others, each	0.03	0.05	0.05	0.05	0.05	0.05
Others total	0.10	0.15	0.15	0.15	0.15	0.15
Aluminum	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder

1/ Alloy requirements are stated as percent maximum, except where a range is specified. Test results may be rounded in accordance with the rounding-off method of ASTM E 29.

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TABLE II. Maximum acceptable discontinuities in aluminum-alloy castings (maximum permissible radiograph in accordance with ASTM E 155). 1/, 2/, 3/, 4/

Discontinuity	Radiograph 8/	Grade A inch		Grade B inch		Grade C inch		Grade D inch	
		1/4	3/4	1/4	3/4	1/4	3/4	1/4	3/4
Gas holes 5/	1.1	None		1	1	2	2	5	5
Gas porosity (round)	1.21	None		1	1	3	3	7	7
Gas porosity (elongated)	1.22	None		1	2	3	4	5	5
Shrinkage cavity	2.1	None		1	NA 6/	2	NA 6/	3	NA 6/
Shrinkage porosity or sponge	2.2	None		1	1	2	2	4	3
Foreign material (less dense material)	3.11	None		1	1	2	2	4	4
Foreign material (more dense material)	3.12	None		1	1	2	1	4	3
Segregation	3.2	None		None		None		None	
Cracks	NA 6/	None		None		None		None	
Cold shuts	NA 6/	None		None		None		None	
Surface irregularity	NA 6/	- - - Not to exceed tolerance 7/ - - -							
Core Shift	NA 6/	- - Not to exceed tolerance 7/ - - -							

- 1/ Use 1/4 inch radiographs for casting thicknesses to 1/2 inch inclusive. Use 3/4 inch radiographs for casting thicknesses over 1/2 inch to 2 inches inclusive.
- 2/ When two or more types of defects are present to an extent equal to or not significantly better than the acceptance standards for respective defects, the parts will be rejected.
- 3/ When two or more types of defects are present and the predominating defect is not significantly better than the acceptance standard, then the parts shall be considered borderline.
- 4/ Borderline castings may be reviewed for acceptability by competent engineering personnel and Government quality control.

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- 5/ Gas holes or sand spots and inclusions allowed by this table shall be cause for rejection when closer than twice their maximum dimension to an edge or extremity of a castings.
- 6/ Not available. Use 1/4 inch for all thicknesses.
- 7/ Tolerance shall be defined as the amount of metal which can be removed when excising a defect without reducing the dimensions in the affected locations below the minima specified.
- 8/ ASTM E 155 Volume I reference radiograph numbers.

TABLE III. Mechanical properties of specimens cut from designated areas of castings (see 4.5.4). 1/, 2/

Alloy	Strength class number	Minimum tensile strength, ksi	Minimum yield strength at 0.2 percent offset, ksi <u>5/</u>	Minimum elongation in 2 inches, 4D or 4.5√A percent <u>3/</u> , <u>4/</u>
A201.0-T7	1	60.0	50.0	3
	2	60.0	50.0	5
354.0-T6	1	47.0	36.0	3
	2	50.0	42.0	2
C355.0-T6	1	41.0	31.0	3
	2	44.0	33.0	3
	3	50.0	40.0	2
A356.0-T6	1	38.0	28.0	5
	2	40.0	30.0	3
	3	45.0	34.0	3
A357.0-T6	1	45.0	35.0	3
	2	50.0	40.0	5
359.0-T6	1	45.0	35.0	4
	2	47.0	38.0	3

- 1/ For any casting process; i.e., special mold, permanent mold or sand mold with chills may be used. Properties in other areas will vary with mold process and foundry techniques used, but shall be inspected under foundry control (see 3.2.1). Special negotiated properties may be required by the drawing note referenced in the acquisition document.

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- 2/ Tensile and yield test results may be rounded to the nearest 0.1 ksi, and each value of the elongation above 1.0 percent may be rounded to 0.5 percent. Rounding shall be in accordance with the rounding-off method of ASTM E 29.
- 3/ D = Diameter of test specimen.
- 4/ A = Cross-sectional area of test specimen.
- 5/ For any alloy, yield strength will be reasonably consistent throughout the casting. This should be considered when selecting combinations of classes from Tables III and IV.

TABLE IV. Mechanical properties of specimens cut from any area of casting (see 4.5.4). 1/, 2/

Alloy	Strength class number	Minimum tensile strength, ksi	Minimum yield strength at 0.2 percent offset, ksi	Minimum elongation in 2 inches, 4D or 4.5√A percent <u>3/</u> , <u>4/</u>
A201.0-T7	10	60.0	50.0	3
	11	56.0	48.0	1.5
354.0-T6	10	47.0	36.0	3
	11	43.0	33.0	2
C355.0-T6	10	41.0	31.0	3
	11	37.0	30.0	1
	12	35.0	28.0	1
A356.0-T6	10	38.0	28.0	5
	11	33.0	27.0	3
	12	32.0	22.0	2
A357.0-T6	10	38.0	28.0	5
	11	41.0	31.0	3
	12	45.0	35.0	3
359.0-T6	10	45.0	34.0	4
	11	40.0	30.0	3

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- 1/ For any casting process; special mold, permanent mold or sand mold with chills may be used. Special negotiated properties may be required by the drawing note referenced in the acquisition document.
- 2/ Tensile and yield test results may be rounded to the nearest 0.1 ksi, and each value of the elongation above 1.0 percent may be rounded to 0.5 percent. Rounding shall be in accordance with the rounding-off method of ASTM E 29.
- 3/ D = Diameter of test specimen.
- 4/ A = Cross-sectional area of test specimen.

TABLE V. Solution heat-treating conditions.

Alloy	Solution heat-treating temperature, °F	Recommended soaking time in hours	Temper after solution treatment
A201.0	945 to 965 incl followed by 965 to 985 incl	2 minimum at 945 to 965 followed by 8 to 24 incl at 965 to 985 <u>1/ 2/</u>	-T4
354.0	980 to 995 incl	10 to 12 incl	-T4
A357.0	980 to 1020 incl	8 to 20 incl	-T4
359.0	980 to 1010 incl	10 to 14 incl	-T4

- 1/ Soaking time varies with section thickness and grain size of castings. Castings may be quenched from the solution heat-treating temperature into a water bath at 150°F to 190°F, a water bath at room temperature, or an aqueous solution of polyalkylene glycol, provided that specified requirements are met (see 3.5).
- 2/ Quench delay time shall be in accordance with MIL-H-6088.

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TABLE VI. Aging (precipitation) heat treatments. 1/

Alloy	Recommended aging temperature (°F)	Recommended soaking time in hours	Temper after aging treatment
A201.0	360-380 <u>2/</u>	5	-T7
354.0	300-320 330-350	10-12 6-10	-T61 -T-62
A357.0	300-320	8	-T61
359.0	300-320 330-350	10-12 6-10	-T61 -T62

1/ No quenching required. Cool in still air outside furnace.

2/ Preceded by 24 hours minimum at room temperature.